

BASELINE ENERGY USE BASED RESIDENTIAL LIGHTING LOAD CURVE ESTIMATION: A CASE OF SURABAYA

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Abstract

Residential lighting is one of important appliances that, in total, consume large amount of electricity. Establishment of residential lighting load curve is therefore prominent as the curve will be useful for any further analysis. Nevertheless, it is difficult to develop residential lighting load curve when the residential energy consumption is measured using conventional metering or other power monitoring device. This paper presents estimation of residential lighting load curve using Baseline Energy Use method. A survey has been conducted to collect relevant data of lighting utilization in Surabaya. Important findings from the survey include determination of number of each lamp type, average number of lamps per household, total number of lamps in households, and average daily operating hours. Considering a 96.2% share of ownership which consist of incandescent, fluorescent, and compact fluorescent lamp, it is found from the analysis that the lighting peak load is occurred at 7 PM with average wattage per household of 100.1 W. Meanwhile, residential sector's lighting peak load is reached 76.3 MW. In addition, no coincidence found when the lighting load curve compared to the adjusted system loading curve.

Keywords: Baseline Energy Use, Residential Lighting, Lighting Load Curve, lamp utilization.

1. Introduction

Lighting system is one of important household appliances which significantly contributed toward monthly household's energy expenditure. Establishment of residential lighting load curve is therefore prominent as the curve will be useful for any further analysis. Nevertheless, it is difficult to develop residential lighting load curve when the residential energy consumption is measured using conventional metering device. A study of baseline residential lighting energy use was conducted by Tribwell and Lerman [1]. A survey was carried out to establish actual on-hours for all lights in a sample of 161 residences in Northwest, US. The information was used to establish cost-effective lighting to be implemented in the residential sector.

This paper is focused on the development of lighting load curve through the utilization of Baseline Energy Use (BEU) method. Initially obtained from the lamp utilization survey, the load curve is constructed as an estimation to help the decision maker in analyzing

possible policy related with the residential power sector management. This paper is organized as follows; the method used in the study is presented in the next section, results and discussion is followed subsequently, and finally conclusion is presented.

2. Methods

In order to obtain the BEU for lamp utilization, two broad stages are conducted in this research. Firstly, a survey of lamp utilization is carried out to obtain types of lamps used in the household, accordingly with their wattage. Selected study area and boundary participant are initially defined. In addition, number of households to be surveyed is followed to the minimum sample requirement providing the predetermined margin of error is 5% with confidence level of 95%. In this research, the required sample size (SS) is determined as:

$$SS = \frac{Z^2 (p)(1-p)}{c^2} \tag{1}$$

where Z is Z value (e.g. 1.96 for 95% confidence level); p is percentage picking a choice, expressed as decimal (0.5 used for sample size needed); and c is confidence interval, expressed as decimal. For finite population, providing the predetermined population size (pop), corrected SS can be determined as:

$$corrected\ SS = \frac{SS}{1 + \frac{SS-1}{pop}} \tag{2}$$

Another quick way to determine the required sample size is by using the sample size table, which is available online as shown in [2]. In this study, three types of lamps, i.e. Incandescent Lamp (IL), Fuorescent Lamp or Tubular Lamp (TL), and Compact Fluorescent Lamp (CFL) are considered to be asked regarding to their utilization in the questionnaire. As shown in Figure 1 below, the questionnaire template is adopted from [3].

No	Lamp Type (Please tick: v)			Watt	Area	Daily operating hour (Please tick: v)												Total hour
	IL	TL	CFL			1	2	3	18	...	22	23	24			
						AM						PM						
1.																		
2.																		
3.																		
...																		

Figure 1. Questionnaire template to obtain daily lamp utilization in the residential sector.

The BEU for household’s lamp utilization can then be obtained by conducting four essential assessment after the lamp utilization data have been gathered. The following baseline, such as the number of lamps of each lamp type in the surveyed households, average number of lamps per household, estimation of total number of lamps in all households, and average daily operating hour of each lamp, will then be revealed according to the followings [3]. Number of lamps of each lamp type are obtained by conducting survey. The survey participants are asked to fill up the questionnaire as shown in Fig. 1. The variety of IL, TL, and CFL are obtained from this stage. Furthermore, the result of this initial assessment will be used to determine other data of the following three assessment and other useful characteristic of lighting utilization, such as diversity factor (DF) and coincidence factor (CF).

Average number of lamps per household (ALH) is calculated based on the ratio between number of specific lamp type (SLT) having certain rated watt

which is obtained from the survey and number of survey participants or here is sample size (SS), as:

$$ALH = \frac{SLT}{SS} \tag{3}$$

Total number of lamps in all households is then estimated based on the number of specific lamp type (SLT), sample size (SS), and number of electrified households or here is considered as population size (pop) as:

$$ETLH = \frac{SLT}{SS(pop)} \tag{4}$$

Average daily operating hours (ADH) is determined based on total number of operating hour of the lamp type in the surveyed households (TNHL), and total number of lamp type in the surveyed households (TNL) as [4]:

$$ADH = \frac{TNHL}{TNL} \tag{5}$$

3. Results and Discussion

As described in earlier section, number of household to be surveyed is determined based on Equation (1) and (2). Therefore, a total number of required sample is 384 respondents which is equivalent to the same number of household, considering 762,248 households in Surabaya. The questionnaire is then distibuted randomly to all Surabaya areas, consisting of West, East, South, North, and Central. Composition of questionnaire distribution for lamp utilization survey in Surabaya is presented in the following figure.

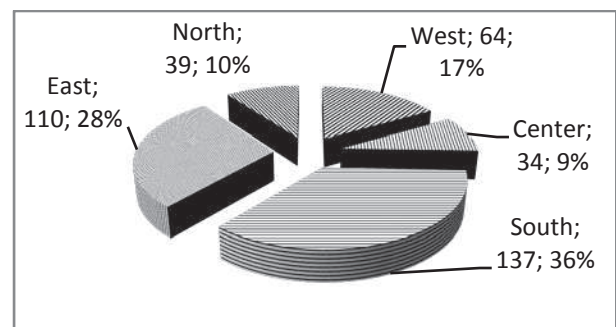


Figure 2. Questionnaire distribution for lamp utilization survey in Surabaya

Form Fig. 2, we can see that the South Surabaya area has the largest respondents with 137 households

representing 36% of total number of participant whereas the Central area has the least participants with only 34 households, accounted for only 9% of the total number of participant. Using Equation (3) to (4), baseline energy use for lighting utilization in Surabaya is obtained for three types of lamp, as presented in the following table.

Table 1. Lamp Utilization Characteristics in Residential Sector: A Case of Surabaya

A	B	C	D	E	F
5 W IL	66	0.17	131,011	1.7	4.1
10 W IL	50	0.13	99,251	1.3	7.4
15 W IL	25	0.07	49,626	0.6	7.5
20 W IL	14	0.04	27,790	0.4	7.1
25 W IL	10	0.03	19,850	0.3	7.8
40 W IL	23	0.06	45,655	0.6	3.9
10 W TL	146	0.38	289,813	3.7	7.0
15 W TL	141	0.37	279,888	3.5	6.2
18 W TL	24	0.06	47,641	0.6	4.4
20 W TL	130	0.34	258,053	3.3	8.6
25 W TL	31	0.08	61,536	0.8	7.3
36 W TL	29	0.08	57,566	0.7	8.7
40 W TL	62	0.16	123,071	1.6	11
5 W CFL	90	0.23	178,652	2.3	6.1
7 W CFL	106	0.28	210,412	2.7	6.5
8 W CFL	273	0.71	541,911	6.8	4.0
9 W CFL	89	0.23	176,667	2.2	6.2
10 W CFL	239	0.62	474,420	6.0	6.9
11 W CFL	254	0.66	504,195	6.4	4.2
12 W CFL	129	0.34	256,068	3.2	4.1
13 W CFL	48	0.13	95,281	1.2	8.1
14 W CFL	153	0.40	303,708	3.8	3.2
15 W CFL	562	1.46	1,115,582	14.1	4.9
18 W CFL	663	1.73	1,316,069	16.6	6.0
20 W CFL	227	0.59	450,600	5.7	6.0
23 W CFL	165	0.43	327,528	4.1	8.5
24 W CFL	24	0.06	47,641	0.6	7.1
25 W CFL	29	0.08	57,566	0.7	4.0
28 W CFL	28	0.07	55,581	0.7	7.2
30 W CFL	14	0.04	27,790	0.4	7.6

- A = Type of lamp with its certain rated wattage
- B = Number of specific lamp type obtained from survey
- C = Average number of lamps per household
- D = Total number of lamps in all households (estimation)
- E = Share of certain type of lamp toward total estimated lamp (in percentage)
- F = Average daily operating hours

As seen in Table 1, the lamp share of ownership in terms of three types of lamp in Surabaya is obtained as follows: CFL having the largest share of ownership with 77.4% followed with TL with 14.1% and IL with the least share of 4.7%, aggregated for 96.2%. Please be noted that only lamp type having ten or more in quantity calculated during the survey are taken into account. It

also shown that the CFL 18 W is the most widely used in the household sector, accounted for 16.6% whereas IL 25 W is least use with only 0.3% in share. It also found that 14 W CFL having the shortest daily usage with only 3.2 hours contrast to 40 W TL with 11 hours. Fig. 2 to 4 depict the calculated average daily operating hours for three lamp types with its various power rating.

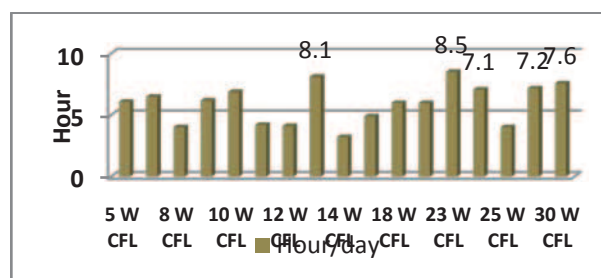


Figure 3. Average daily operating hours: Compact Fluorescent Lamp (Survey 2012)

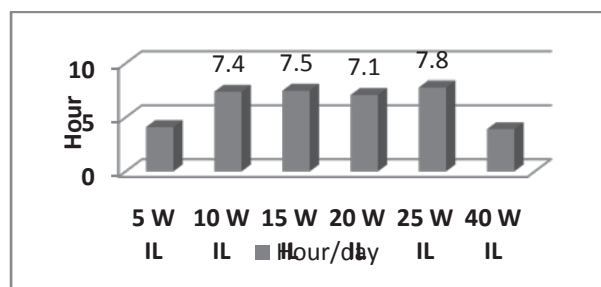


Figure 4. Average daily operating hours: Incandescent Lamp (Survey 2012)

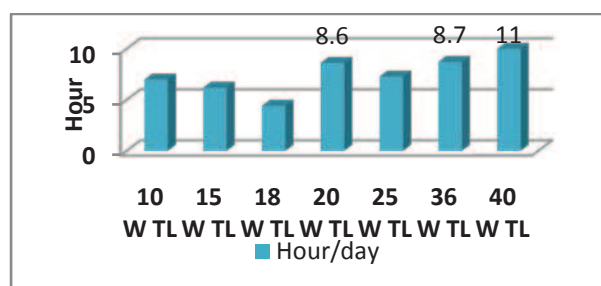


Figure 5. Average daily operating hours: Fluorescent Lamp or Tubular Lamp (Survey 2012)

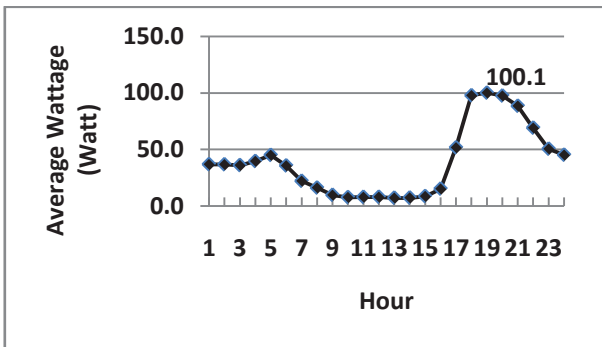


Figure 6. Estimation of typical lighting load curve per household in Surabaya

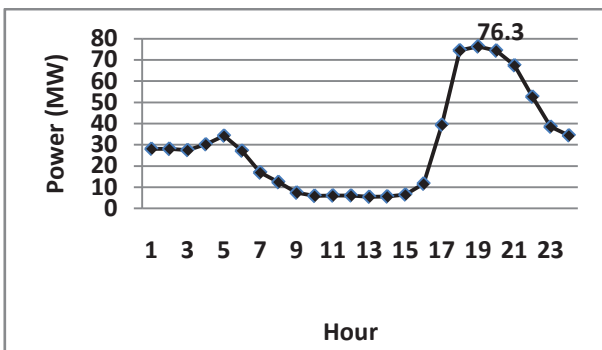


Figure 7. Estimation of typical lighting load curve for residential sector in Surabaya

Fig. 6 and 7 depict estimation of typical lighting load curve per household and for residential sector in Surabaya, respectively, taken into account 96.2% in lamp share of ownership. The curve is constructed based on each lamp power rating and their hourly usage. The peak load of lamp power consumption per household is estimated occurred at 7 PM with 100.1 W. Data consisting all lamps power rating together with their total hourly usage as gathered in Fig. 1 are tabulated to obtain hourly total lamp power (W). In Fig 6, divided the hourly total power into total number of participant, the average hourly lamp power consumption per household can be determined. Similarly, multiplying average hourly lamp power consumption per household with total number of electrified households, we can obtain the estimates lighting load curve for residential sector in Surabaya, as depicted in Fig. 7. The peak load for residential lighting load in Surabaya istimated occurred at 7 PM with 76.3 MW.

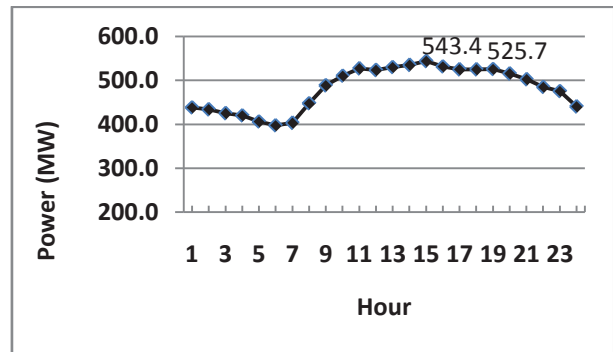


Figure 8. Adjusted average system load curve for Surabaya distribution area (PT. PLN APD Jatim, June – September 2011, modified)

This study also considers developing the system load curve for Surabaya to observe coincidence between lighting load and system load. The 2011 original system load curve for Surabaya distribution area was collected from PT. PLN APD Jatim [5]. The system load curve data during June – September 2011 was considered to be observed for the purpose of month similarity with the survey activity which was held during June – September 2012. This study uses assumption that no significant changes have been made during one year, particularly regarding to the lamp utilization in the residential sector.

Average value of peak load during June – September 2011 was obtained from the original data. However, due to large area of PLN’s Surabaya Distribution System, we have decided to reduce the coverage area by removing several transformers supplying into those areas, including those supplies industrial clusters. As seen on Fig. 8, the adjusted system load for Surabaya Distribution System during June – September 2011 shows its peak load at 3 PM with 543.4 MW. Meanwhile, the average power consumption at 7 PM was slightly lower than that with 525.7 MW. This means the lighting load curve is not coincidence with the system load at 7 PM, although the loading for several areas such as Rungkut Industrial estate, Waru, and West Surabaya are excluded. The system load is started to increase at 8 AM when most of industry began its operation. Commercial office followed at 9 AM, and shopping center started at 10 AM. In fact, the residential sector also contributed for the cooling load from the utilization of air conditioning system, which in turn increases the hourly power demand.

4. Conclusion

In this paper, baseline energy use method is applied for estimating lighting load curve in residential sector. The selected study area is Surabaya. Primary data are

collected from the survey. From the analyses, we found that residential lighting peak load occurred at 7 PM with 76.3 MW. Another finding is that residential lighting load curve has no coincidence with the system loading curve. In fact, Surabaya is the second largest city in Indonesia after Jakarta where its system load curve is also influenced by industrial and commercial activities beside residential load. Also, lighting is only part of whole residential appliances. It can be concluded that the system load curve of Surabaya has a narrower valley than that in lighting load curve. From having such lighting as well as system curve, there will be opportunities to influence the loading curve for the purpose of energy efficiency and conservation, for example through loading management.

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